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4 JUN 2003

3. Full name, address and postcode of the or of each applicant (underline all surnames)

Andrew FOX
4 St Pauls Street
Chippenham
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United Kingdom

Patents ADP number (if you know it)

If the applicant is a corporate body, give the country/state of its incorporation

8645194001

4. Title of the invention

ANTENNA SYSTEM

5. Name of your agent (if you have one)

Haseltine Lake

"Address for service" in the United Kingdom to which all correspondence should be sent (including the postcode)

Imperial House
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London
WC2B 6UD

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Date of filing
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Number of earlier application

Date of filing
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Description 15

Claim(s) 3

Abstract 1

Drawing(s) 3 + 3 *Fig*

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Request for preliminary examination and search (*Patents Form 9/77*) 1

Request for substantive examination (*Patents Form 10/77*)

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11. I/We request the grant of a patent on the basis of this application.

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Mr D C O'Connell

[0117] 910 3200

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ANTENNA SYSTEM

This invention relates to an antenna system, and in particular to an antenna system that allows a dielectric resonator antenna to be used for relatively wideband microwave or radio frequency signal transmission and reception.

Dielectric resonator antennas are known, in which a suitably sized and shaped piece of low loss dielectric material is mounted on a ground plane. In order to transmit a signal, a specific mode of operation is excited by feeding an electrical signal into the dielectric material.

Dielectric resonator antennas are to be contrasted with patch antennas, which are commonly used in portable transceiver devices such as mobile phones, in which a patch of a conductive material is used as an antenna. Although dielectric resonator systems sometimes appear superficially similar to patch antenna systems, they are actually used in completely different ways. In particular, they are typically operated in different excitation modes, which radiate by different mechanisms, and so it follows that the arrangements for feeding the required electrical signals into the antenna are also completely different.

It is generally desirable to have a very small antenna but with a wide bandwidth. However, this is not generally possible with dielectric resonator antennas (DRAs). This is due to the fact that a wide bandwidth is associated with a low dielectric constant DRA. Since the size of the DRA is inversely related to the square root of the dielectric constant, a low

dielectric constant will result in a wide bandwidth antenna but will cause the DRA to be larger in size.

5 EP-A-0801436 describes the use of dielectric resonator antennas, and discloses one proposed solution to a problem with dielectric resonator antennas, namely their relatively narrow operational bandwidths.

10 According to the present invention, there is provided an antenna system which allows a dielectric resonator antenna to be used to provide a relatively wide transmission bandwidth.

15 In particular, there is provided an antenna system, in which a dielectric resonator is provided with first and second electrical signal inputs, and an electrical signal is fed through the first electrical signal input, and through the second electrical signal input with a significant phase difference.

20 This has the advantage that the antenna bandwidth is increased, allowing the antenna system to be used in wideband applications.

25 In particular, the bandwidth enhancement is achieved while maintaining relatively high field containment, that is, without making the performance of the antenna more sensitive to the presence of nearby metal objects.

30 For a better understanding of the present invention, and to show how it may be put into effect, reference will now be made, by way of example, to the accompanying drawings, in which:-

35 Figure 1 is a schematic illustration of an antenna system in accordance with the present invention.

Figure 2 is a schematic illustration of a second antenna system in accordance with the present invention.

5

Figure 3 is a schematic illustration of a third antenna system in accordance with the present invention.

Figure 4 is a schematic illustration of a fourth antenna system in accordance with the present invention.

Figure 5 is a schematic illustration of a fifth antenna system in accordance with the present invention.

15

Figure 6 is a schematic illustration of a sixth antenna system in accordance with the present invention.

Figure 1 is a schematic side view of an antenna system in accordance with the present invention. A "puck" of dielectric material 10 is sized and shaped to resonate, and therefore act as an antenna, in the desired operational frequency range, and is mounted on a ground plane 12.

The operational bandwidth of the antenna is determined by, amongst other things, the dielectric constant of the dielectric material, and the radius-to-height ratio of the puck (if the puck has a circular cross-section), and these parameters can be chosen in a conventional way to achieve the desired bandwidth in the system shown herein. In this illustrative preferred embodiment of the invention, the dielectric material is in the form of a cuboid, having length : height : width ratios of 2:1:0.8.

35

One conventional way of feeding an electrical signal to a dielectric resonator is by way of a monopole coaxial feed line. However, in the embodiment of the present invention shown in Figure 1, there are two such monopole coaxial feed lines 14, 16, or probes, connected to the dielectric resonator antenna 10 such that they are coupled with its fundamental leaky hybrid electric mode (HEM_{11d}). The position of each of the probes can be determined in a way which generally corresponds to the conventional way of determining feed positions, namely locating and dimensioning the probes such that a desired impedance is achieved, based upon the mode which is to be excited.

15 An input electrical signal is fed to the two feed lines 14, 16, such that there is a substantial phase difference between the signals fed to the two lines. The phase difference is preferably close to 180°, or to an odd multiple of 180° (for example, 540°, 900°, etc). However, the phase difference should preferably not be exactly equal to 180°, or to an odd multiple of 180°. For example, the phase difference might advantageously be in the range of 160° - 200° (or 520° - 560°, or 880° - 920°, etc); or in the range of 150° - 210° (or 510° - 570°, or 870° - 930°, etc); or in the range of 140° - 220° (or 500° - 580°, or 860° - 940°, etc); or in the range of 140° - 160° or 200° - 220° (or 500° - 520°, 560° - 580°, 860° - 880° or 920° - 940°, etc).

30 This has the effect that the two feed lines cause resonances, which interact with each other in such a way that the frequency response of the antenna has two peaks, with the frequencies of the two peaks being slightly offset from each other such that the antenna has a broadened operational bandwidth. For example,

defining the operational bandwidth as being the range of frequencies at which the return loss is better than 10dB, if there is a 150° phase difference between the signals on the two feed lines, the operational
5 bandwidth may be doubled compared with a conventional dielectric resonator antenna having a single feed line.

Figure 2a is a side view and Figure 2b is a plan view of an alternative antenna system in accordance with the
10 present invention, in which the electrical signal is fed to the antenna through pads.

Specifically, a dielectric resonator antenna 20 is mounted on a substrate 22. As in the Figure 1
15 embodiment, the dielectric material 20 is in the form of a cuboid, which is sized and shaped to resonate, and therefore act as an antenna, in the desired operational frequency range, preferably having length : height : width ratios of 2:1:0.8.

20

In this case, the electrical signal is supplied along an input copper microstrip line 24, which has an impedance matching section 26, the form of the microstrip line 24 and the impedance matching section
25 26 being generally conventional. The electrical signal is supplied to the dielectric material 20 through a pad 28, which is located below the dielectric material. Again, the form of the pad 28 is generally conventional, although it will be noted that the pad 28
30 extends across the whole width of the dielectric material 20. In this illustrated embodiment of the invention, the pad 28 extends along the length of the dielectric material for a distance which is equal to 0.4 times the height of the dielectric material.

35

In this case, however, a further microstrip line 30 leads from the pad 28 to a second pad 32, which is located below the dielectric material, but extending across the whole width of the dielectric material, at the opposite end thereof. The electrical signal is therefore also applied to the dielectric resonator antenna 20 at this opposite end.

The dimensions of the dielectric material 20, and the positions of the pads 28, 32, are chosen such that the applied electrical signal excites the fundamental leaky hybrid electric mode (HEM_{11d}) at the desired frequency.

Again, in this illustrated embodiment of the invention, the pad 32 extends along the length of the dielectric material for a distance which is equal to 0.4 times the height of the dielectric material.

As in the embodiment of Figure 1, the input electrical signal is fed to the two pads 28, 32 such that there is a substantial phase difference between the signals fed to the two lines.

In preferred embodiments of the invention, the phase difference arises as a result of the additional path length which the signals must travel along the further microstrip line 30. For example, a microstrip line 30 having a length of about 20mm may produce a phase difference of about 180° in the case of signals at a frequency of 5GHz, but the phase difference will be correspondingly smaller (or larger) for signals at lower (or higher) frequencies. However, any phase shift element may be inserted into the line 30, if desired.

Again, the phase difference is preferably close to 180° , or to an odd multiple of 180° (for example, 540° , 900° , etc). However, the phase difference should not be exactly equal to 180° , or to an odd multiple of 180° . For example, the phase difference might advantageously be in the range of $160^\circ - 200^\circ$ (or $520^\circ - 560^\circ$, or $880^\circ - 920^\circ$, etc); or in the range of $150^\circ - 210^\circ$ (or $510^\circ - 570^\circ$, or $870^\circ - 930^\circ$, etc); or in the range of $140^\circ - 220^\circ$ (or $500^\circ - 580^\circ$, or $860^\circ - 940^\circ$, etc); or in the range of $140^\circ - 160^\circ$ or $200^\circ - 220^\circ$ (or $500^\circ - 520^\circ$, $560^\circ - 580^\circ$, $860^\circ - 880^\circ$, or $920^\circ - 940^\circ$, etc).

Moreover, the presence of the microstrip line 30, running parallel to the edge 34 of the dielectric resonator antenna 20, has an effect on the resonances excited within the dielectric material. Therefore, a tuning screw 36 is provided in the area between the dielectric resonator antenna 20 and the microstrip line 30, half way along the length of the antenna 20. The tuning screw 36 acts as a choke in the magnetic field between the dielectric resonator antenna 20 and the microstrip line 30, and adjustment of the amount by which the screw 36 protrudes from the substrate 22 into the magnetic field makes it possible to adjust the degree of coupling between the antenna 20 and the microstrip line 30. This adjustment can take place for example after manufacture, and the frequency response of the antenna system can then be trimmed to give the required properties.

Figure 3 shows a further alternative antenna system in accordance with the present invention, in which the electrical signal is fed to the antenna through pads. Specifically, Figure 3a is a side view and Figure 3b is a plan view of an antenna system from which the

dielectric resonator itself has been removed for clarity.

Specifically, a dielectric resonator antenna 40 is
5 mounted on a substrate 42. As before, the dielectric material 40 is in the form of a cuboid, having length : height : width ratios of 2:1:0.8, which is sized and shaped to resonate, and therefore act as an antenna, in the desired operational frequency range. In this case,
10 the electrical signal is supplied along an input copper microstrip line 44, which has an impedance matching section 46, the form of the microstrip line 44 and the impedance matching section 46 being generally conventional. The electrical signal is supplied to the
15 dielectric material 40 through a pad 48, which is located below the dielectric material. Again, the form of the pad 48 is generally conventional, although it will be noted that the pad 28 extends across the whole width of the dielectric material 20. Again, in this
20 illustrated embodiment of the invention, the pad 48 extends along the length of the dielectric material for a distance which is equal to 0.4 times the height of the dielectric material.

25 A further microstrip line 50 leads from the pad 48 to a second pad 52, which is located below the dielectric material, and extends across its whole width, at the opposite end thereof. Again, in this illustrated embodiment of the invention, the pad 52 extends along
30 the length of the dielectric material for a distance which is equal to 0.4 times the height of the dielectric material.

The electrical signal is therefore also applied to the
35 dielectric resonator antenna 40 at this opposite end. Again, a tuning screw 56 is provided between the

dielectric resonator antenna 40 and the microstrip line 50.

As in the embodiment of Figure 1, the input electrical signal is fed to the two pads 48, 52 such that there is a substantial phase difference between the signals fed to the two lines.

Again, the phase difference is preferably close to 180° , or to an odd multiple of 180° (for example, 540° , 900° , etc). However, the phase difference should not be exactly equal to 180° , or to an odd multiple of 180° . For example, the phase difference might advantageously be in the range of $160^\circ - 200^\circ$ (or $520^\circ - 560^\circ$, or $880^\circ - 920^\circ$, etc); or in the range of $150^\circ - 210^\circ$ (or $510^\circ - 570^\circ$, or $870^\circ - 930^\circ$, etc); or in the range of $140^\circ - 220^\circ$ (or $500^\circ - 580^\circ$, or $860^\circ - 940^\circ$, etc); or in the range of $140^\circ - 160^\circ$ or $200^\circ - 220^\circ$ (or $500^\circ - 520^\circ$, $560^\circ - 580^\circ$, $860^\circ - 880^\circ$, or $920^\circ - 940^\circ$, etc).

In this case, however, there is a third pad 54, which is located centrally under the dielectric material 40. The primary purpose of the third pad 54 is to provide a stable way of mounting the dielectric material 40 to the substrate 22. However, its presence will also have an effect on the coupling of the magnetic field generated by the dielectric material 40. It may therefore be necessary either alter the degree of coupling by means of the tuning screw 56, or by reducing the distances by which the pads 48, 52 extend from their respective ends along the dielectric material 40.

Figure 4 is a plan view of an antenna system in accordance with another embodiment of the invention.

The antenna system is similar to that shown in Figure 2, and reference numerals, which are common to the two Figures, refer to corresponding features. The difference is that, in the embodiment of Figure 4, the input feed line 64 is connected to an input line 66, which feeds into the side of the pad 28, rather than into the end. At the opposite end of the dielectric material 20, the input feed line 64 is connected through the microstrip line 30 to an input line 68, which again feeds into the side of the pad 32.

The embodiments of the invention described so far have all involved excitation of the fundamental HEM mode of the dielectric material. However, it is also possible to excite a higher order mode, by appropriate choice of dimensions of the dielectric material, in conjunction with the operating frequency and the positions of the pads which feed the signal into the dielectric material.

Figure 5 is a plan view illustrating an antenna system in accordance with another embodiment of the invention, in which a higher order mode is excited.

A dielectric resonator antenna 80 is mounted on a substrate (not shown). The dielectric material 80 is in the form of a cuboid, which is sized and shaped to resonate, and therefore act as an antenna, in the desired operational frequency range, preferably having length : height : width ratios of 6:1:0.8. Thus, compared with the previous illustrated embodiments, the length of the dielectric material is three times greater. The input electrical signal is applied such that it excites a higher order leaky hybrid electric mode, namely the HEM_{13d} mode, of the dielectric material at the desired frequency.

The electrical signal is supplied along an input copper microstrip line 81, which has an impedance matching section 82, the form of the microstrip line 81 and the impedance matching section 82 being generally conventional. At one end, the electrical signal is supplied to the dielectric material 80 through a pad 84, which is located below the dielectric material. Again, the pad 84 extends across the whole width of the dielectric material 80, and extends along the length of the dielectric material for a distance which is equal to 0.4 times the height of the dielectric material.

A further microstrip line 86 leads from the pad 84 to a second pad 88, which is located below the dielectric material 80, but extending across the whole width of the dielectric material, approximately one third of the distance along the dielectric material from the first end. The electrical signal is therefore also applied to the dielectric resonator antenna 80 at this point, and this causes the HEM13d mode to be excited.

Again, in this illustrated embodiment of the invention, the pad 88 extends along the length of the dielectric material for a distance which is equal to 0.4 times the height of the dielectric material.

As in previous embodiments, the input electrical signal is fed to the two pads 84, 88, such that there is a substantial phase difference between the signals fed to the two lines.

In preferred embodiments of the invention, the phase difference arises as a result of the additional path length which the signals must travel along the further

microstrip line 86. However, another phase shift element may be inserted into the line 86, if desired.

Again, the phase difference is preferably close to
5 180°, or to an odd multiple of 180° (for example, 540°, 900°, etc). However, the phase difference should not be exactly equal to 180°, or to an odd multiple of 180°. For example, the phase difference might advantageously be in the range of 160° - 200° (or 520° -
10 560°, or 880° - 920°, etc); or in the range of 150° - 210° (or 510° - 570°, or 870° - 930°, etc); or in the range of 140° - 220° (or 500° - 580°, or 860° - 940°, etc); or in the range of 140° - 160° or 200° - 220° (or 500° - 520°, 560° - 580°, 860° - 880°, or 920° - 940°,
15 etc).

Moreover, a tuning screw 90 is provided in the area between the dielectric resonator antenna 80 and the microstrip line 86, half way along the length of the
20 microstrip line 86. The tuning screw 90 acts as a choke in the magnetic field between the dielectric resonator antenna 80 and the microstrip line 86, and adjustment of the amount by which the screw 90 protrudes from the substrate into the magnetic field
25 makes it possible to adjust the degree of coupling between the antenna 80 and the microstrip line 86.

Figure 6 is a plan view of an antenna system in accordance with another embodiment of the invention.
30 The antenna system is similar to that shown in Figure 5, and reference numerals, which are common to the two Figures, refer to corresponding features. The difference is that, in the embodiment of Figure 6, the input feed line 91 is connected through the impedance
35 matching section 92 to an input line 94, which feeds into the side of the pad 84, rather than into the end.

Further along the dielectric material 80, the input feed line 81 is connected through the microstrip line 86 to an input line 96, which again feeds into the side of the pad 88.

5

Again, therefore, the applied electrical signal excites the HEM13d mode at the desired frequency.

10 It will be appreciated that, by appropriate placement of feed pads, any desired HEM mode can be excited.

The bandwidth enhancement of higher order mode dielectric resonator antennas, such as a dielectric resonator antenna operating in its HEM13d mode, is a
15 highly advantageous application of this invention. A dielectric resonator antenna operating in this mode effectively forms a solid dielectric array. However, higher order modes suffer from a very narrow bandwidth. Conventionally, therefore, in order to make this
20 dielectric array useful, it is necessary to use a very low dielectric constant material. However, by applying the techniques described herein, the bandwidth can be extended to cover a useable range of frequencies. For example, the antenna can be designed to have a
25 bandwidth which covers the 4.9GHz to 5GHz band, or the 5.03 to 5.091GHz band; or the 5.15GHz to 5.25GHz band, or the 5.25GHz to 5.35GHz band, or the 5.725GHz to 5.875MHz band, or any comparable frequency band.

30 In a solid dielectric resonator antenna array, the form of bandwidth enhancement disclosed herein widens the 10dB return loss bandwidth by over a factor 2 and enables full coverage of one of these bands without the need for exact tuning. Such a property leads to a low
35 cost and very compact array.

Using the HEM15d mode instead of the HEM13d mode, even more gain can be obtained at the expense of bandwidth. However, using the bandwidth enhancement technique described herein would make this mode useable for this application.

In the embodiment of Figure 3, described above, an additional pad 54 was provided underneath the dielectric material 40, as well as the two pads 48, 52 to which the electrical signal is applied. The primary function of the additional pad 54 is to give structural support to the dielectric material 40. In a similar way, in the embodiments of Figures 5 or 6, as well as the two pads 84, 88 to which the electrical signal is applied, one or more additional pads could be positioned underneath the dielectric material 80. Such additional pads could be located between the pads 84, 88, or, most advantageously, towards the free end of the dielectric material 80 to give structural support to the dielectric material.

The invention has been described above with reference to a situation in which an electrical signal is supplied to the two probes 14, 16, or to the two pads 28, 32, or 48, 52, or 84, 88, with a phase difference which causes the frequency response of the antenna to have two peaks in its return loss characteristic, spaced such that the operating bandwidth of the antenna is effectively broadened.

30

In particular, in preferred embodiments, the bandwidth of a particular antenna is doubled, whilst keeping the size and dielectric constant of the particular antenna the same. One result of this, for example, is that, given a particular bandwidth requirement, the size of the antenna can be reduced (compared with a

35

conventional device) by using a material with a higher dielectric constant, while still meeting the bandwidth requirements. This has an added advantage of greater near field containment around the antenna caused by the higher dielectric constant. This technology is therefore particularly useful in mobile devices and duplexer-less systems where antenna to antenna isolation is most desirable.

- 10 As an alternative to the situation described above, in which an electrical signal is supplied to the two probes, or the two pads, with a phase difference which causes the frequency response of the antenna to have two peaks in its return loss characteristic, spaced
15 such that the operating bandwidth of the antenna is effectively broadened, it is possible to supply an electrical signal to the two probes 14, 16, or to the two pads 28, 32, or 48, 52, or 84, 88, with a phase difference which causes the frequency response of the
20 antenna to have two peaks in its return loss characteristic, with the two peaks being spaced sufficiently far apart that the antenna can effectively be considered as a dual band antenna.

CLAIMS

1. An antenna system, comprising a dielectric resonator antenna, and means for supplying an electrical signal to first and second points in the dielectric resonator antenna, with a phase difference therebetween, such that the first and second points each couple to a HEM mode of the dielectric resonator antenna.
2. An antenna system as claimed in claim 1, wherein the means for supplying an electrical signal comprise probes.
3. An antenna system as claimed in claim 1, wherein the means for supplying an electrical signal comprise pads connected to a surface of the dielectric resonator antenna.
4. An antenna system as claimed in any preceding claim, comprising means for supplying the electrical signal to the first and second points with a phase difference in the range of 140° - 220° therebetween.
5. An antenna system as claimed in one of claims 1 - 3, comprising means for supplying the electrical signal to the first and second points with a phase difference therebetween, such that a frequency response of the antenna has two peaks in its return loss characteristic, spaced such that an operating bandwidth of the antenna system is effectively broadened.
6. An antenna system as claimed in one of claims 1 - 3, comprising means for supplying the electrical signal to the first and second points with a phase difference therebetween, such that a frequency response of the

antenna has two peaks in its return loss characteristic, spaced such that the antenna system operates as a dual band antenna.

5 7. An antenna system as claimed in claim 3,
 comprising a first pad connected to the surface of the
 dielectric resonator antenna, and a second pad
 connected to said surface of the dielectric resonator
 antenna, and further comprising a microstrip line
10 connecting the first and second pads.

 8. An antenna system as claimed in claim 7, wherein
 the first pad is connected to the surface of the
 dielectric resonator antenna at a first end region
15 thereof.

 9. An antenna system as claimed in claim 8, wherein
 the second pad is connected to the surface of the
 dielectric resonator antenna at a second end region
20 thereof, opposite the first end region.

 10. An antenna system as claimed in claim 9, wherein
 the second pad is connected to the surface of the
 dielectric resonator antenna at a second region
25 thereof, the position of the second region being chosen
 such that a desired HEM mode is excited.

 11. An antenna system as claimed in any preceding
 claim, comprising a tuning screw located adjacent the
30 dielectric resonator.

 12. An antenna system as claimed in claim 3, or in any
 of claims 4 - 11 when appended thereto, further
 comprising at least one additional pad located
35 underneath said surface of the dielectric resonator
 antenna to provide support therefor.

13. An antenna system as claimed in any preceding
claim, wherein the first and second points in the
dielectric resonator antenna are chosen such that a
5 higher order HEM mode is excited, and such that the
antenna effectively forms a solid dielectric array.

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ABSTRACTANTENNA SYSTEM

5 An antenna system includes a dielectric resonator,
provided with first and second electrical signal
inputs. An electrical signal is fed through the first
electrical signal input, and through the second
electrical signal input with a significant phase
difference, for example in the region of 180° .

10

This has the advantage that the antenna bandwidth is
increased, allowing the antenna system to be used in
wideband applications.

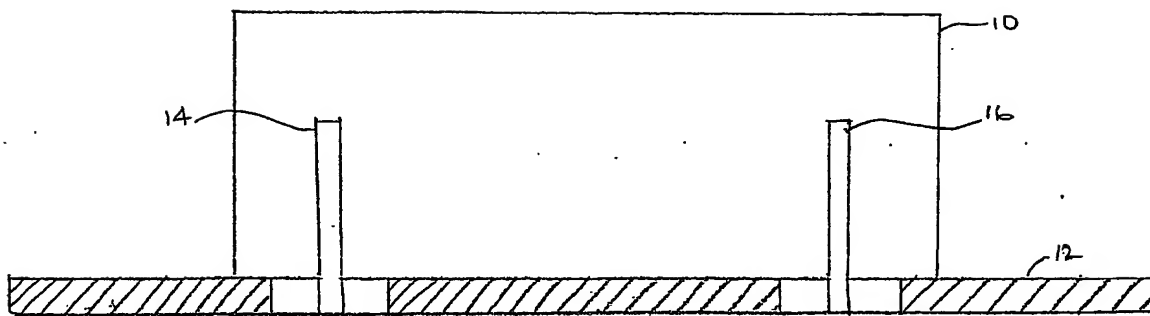


Figure 1

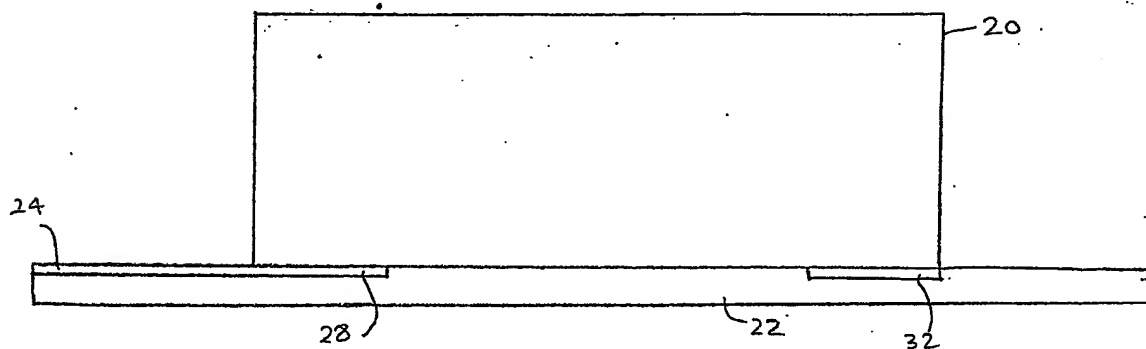


Figure 2a

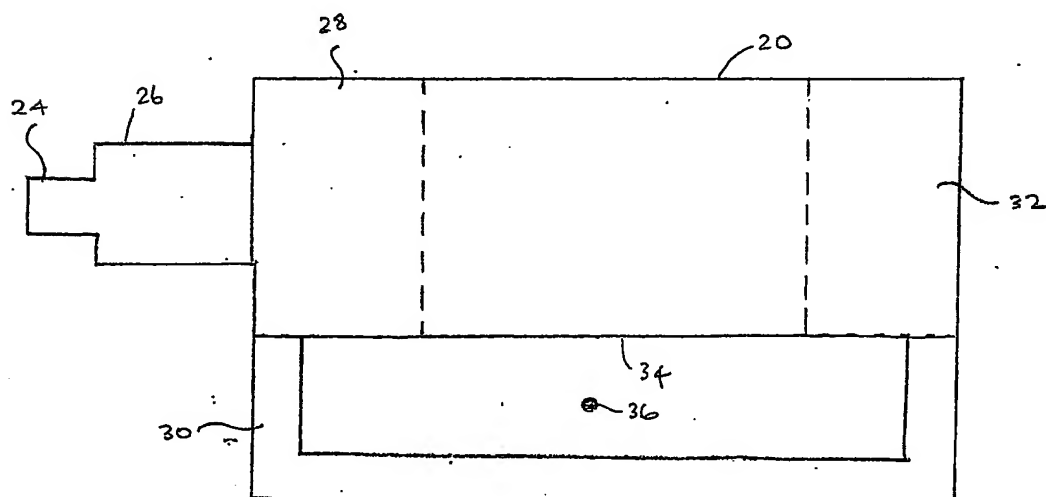


Figure 2b

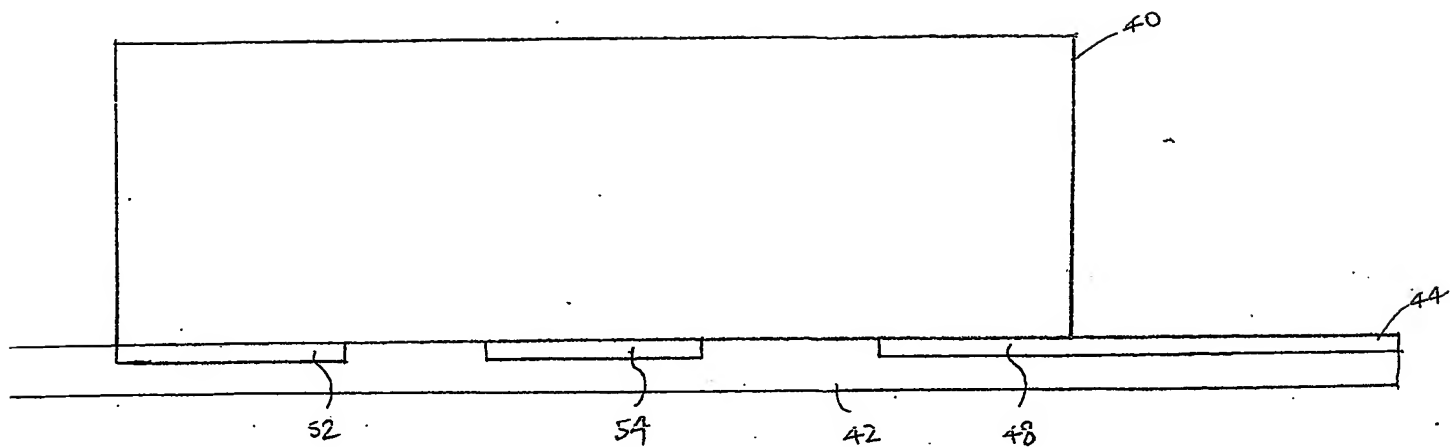


Figure 3a

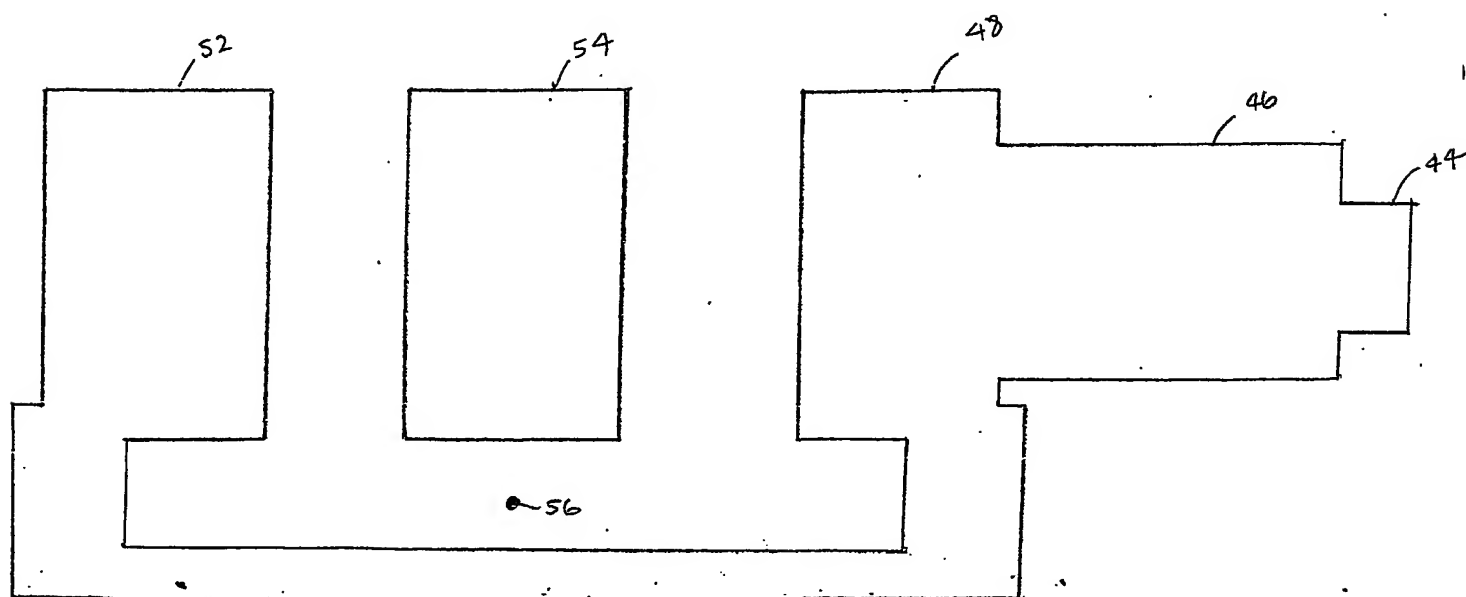


Figure 3b

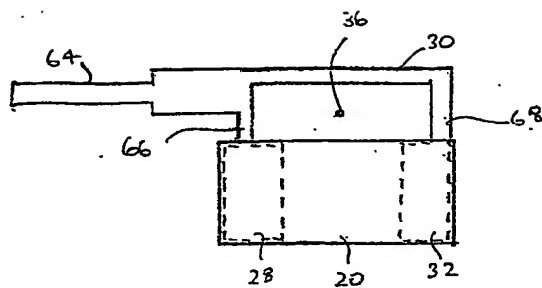


Figure 4

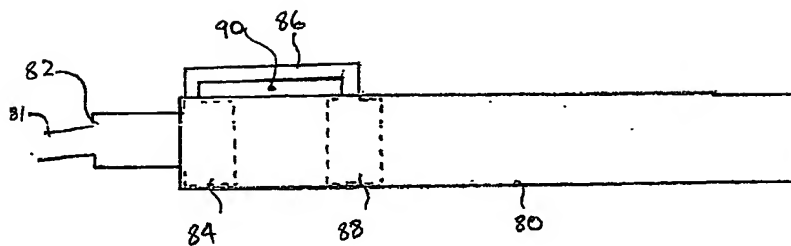


Figure 5

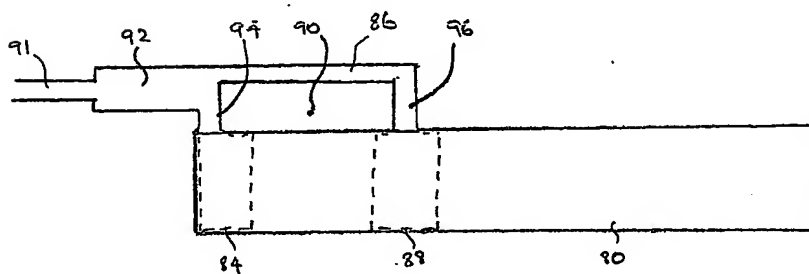


Figure 6

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